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Value Addition and Quality Assessment of Cake Rusk Fortified with Stabilized Rice (*Oryza sativa*) Bran

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Rice Bran (RB) is a main secondary product usually obtained during rice milling. It is a rich in vitamins, amino acids, minerals, antioxidants, and fiber, which are important nutrients for health. In this study, RB was mixed with all-purpose flour at different ratios like 20%, 15%, 10%, and 5%. RB was stabilized with dry heat and acid-treated before using in the cake rusk recipe. RB and wheat flour were investigated for ash, crude protein, nitrogen-free extract (NFE), moisture, crude fat, and crude fiber. Cake rusks were prepared from batter according to the reference method, and chemical analysis was done, including moisture content, crude protein, mineral contents, crude fiber, crude fat, and NFE. Physical parameters such as thickness, spread factor, and average width were measured. Sensory evaluation of cake rusk was done for taste, texture, color, and flavor. All the acquired data were subjected to statistical analysis. Results showed that adding RB increases minerals, antioxidant activity, and dietary fiber in cake rusk without compromising consumer acceptability at an optimal level. Fortification of RB to develop functional bakery products is assumed to be a sustainable approach in value-added products.
Keywords: Rice bran, nutrients, stabilization, chemical analysis, physical parameters.

INTRODUCTION

Bakery products, such as cake rusk, are widely consumed due to their extended shelf life, convenience, and sensory appeal; however, many refined cereal-based snacks are low in dietary fibre, micronutrients, and health-promoting phytochemicals, creating an opportunity for nutritional enhancement through fortification. Recent product development studies have explored the incorporation of cereal by-products into rusks and similar twice-baked goods to improve nutritional quality while maintaining acceptable sensory attributes (Kumari & Gupta, 2024).

Paddy rice (*Oryza sativa* L.) is the main food, which meets the needs of more than 50% of the global population. The world's leading rice consumers and producers are located in emerging market economies in Asia. The region produces nearly 90% of the world's rice and consumes about 87%. The top eight of the world's top ten rice-producing economies (≈ 540 million tonnes) belong to emerging countries in Asia. The world's largest rice producer is China, accounting for approximately 30%, followed by India, which accounts for 27%. Indonesia and Bangladesh each account for 7%, Vietnam accounts for 5%, Thailand accounts for 4%, and Myanmar and the Philippines each account for 1%. 148.5 million tons and 116.48 million tons. Pakistan, being an agricultural country, also contributes to rice production with an output of ≈ 10.98 million tonnes (paddy) and is known as the lower Sindh districts' dominant cash crop (Ali et al., 2025). Processing of rice includes multiple steps and produces different by-products (Gadal et al., 2019).

Among these by-products, rice bran (RB), a major one obtained during rice milling, is nutritionally rich. It contains appreciable amounts of dietary fibre, quality protein, essential fatty acids, vitamins (notably B-complex and vitamin E homologues), minerals, and a complex of bioactive compounds including γ-oryzanol, tocopherols/tocotrienols, and phytosterols that contribute antioxidant and lipid-modulating activities. These compositional features make rice bran an attractive ingredient for value-added bakery products(Eng & Mohd Rozalli, 2022; Shahzad et al., 2021).

Despite its potential, raw rice bran is highly susceptible to hydrolytic and oxidative rancidity because of endogenous lipase and lipoxygenase activities; therefore, stabilization (thermal, microwave, extrusion, steam, or autoclave treatments and other emerging methods) is required to inactivate these enzymes and preserve bran quality for human

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food applications. The efficiency of stabilization and its effects on nutrient retention and functionality are active areas of research(Saikia & Deka, 2011; Yılmaz Tuncel, 2023).

RB in bakery items will help to reduce the malnutrition problems among people of Pakistan, and it is found to be increasingly introduced in multiple food productions to increase the nutritional profile of processed foods. It comprises a good amount of fiber content, and keeping in view for its multiple benefits, it is used to develop value-added and functional foods that have a high market demand. RB supplementation is found in multiple products like noodles, cakes, pasta, breads, and ice cream. This supplementation does not affect the textural and functional properties of these products significantly. Its functional components, such as Oryzanol, have appeared to have diversified health benefits like growth promotion, stimulation of the hypothalamus, and hypolipidemic effect. Prior experimental studies on bread, cookies, cakes, and rusk formulations provide practical benchmarks for substitution levels and analytical methods (proximate analysis, texture profile, colorimetry, shelf-life testing, and sensory evaluation) (Espinales et al., 2022; Evangelista & Schönlechner, 2025).

Cake rusks are liked by almost every age group. Rice contains nearly 7-8% protein, 3% fiber, 80% carbohydrate, and 3% lipid content. Rice grain consists of 5% rice bran, of which nearly 12% to 19% is oil. The bran part of rice is considered highly beneficial as it contains a great number of nutritious components, contributing to controlling diabetes. It is considered to have high contents of fibers, micro and macronutrients, and different trace elements. However, before that, when there was no research work on bran, it was being used as animal fodder and as remaining compost matter. In developing countries, this is utilized for humans to save the world from the crisis of hunger and to cater to the requirements of food and malnutrition (Priyadarsani et al., 2025).

Keeping this scenario in mind, current research was conducted to add RB with having high content of fibre to the cake rusk. To utilize waste materials of the rice milling industry for the value-added cake rusk production to enhance the nutritional profile of the cake rusk (Issara & Rawdkuen, 2016). The current study aimed to achieve the prescribed objectives such as to utilize waste materials of the rice milling industry for the value-added cake rusk development and to check the acceptability of the consumer for bran-enriched cake rusk

MATERIALS AND METHODS

***Raw Material Procurement*:** In the current research, RB (freshly milled) was directly procured from Kisan Rice Mill and General Mills, Rahim Yar Khan, whereas, remaining required raw material, *i.e.*, all-purpose flour (wheat), eggs, baking powder, shortening, vanilla flavor, salt, granulated cane sugar was acquired from the nearby market of in Rahim Yar Khan (RYK). In addition, chemicals required in this study were bought from a scientific store to possible quality standards. Raw materials were collected in plastic bags to avoid any contamination and stored at room temperature. Further, the raw material collected was transferred to the laboratory of the IFST, KFUEIT, Rahim Yar Khan.

***Handling the Raw Material*:** Collected RB was introduced to the grinder for getting finely ground powder. Further, it was passed through a mesh screen having a size of 60 to homogenize the particle size, and then packed and air-tight sealed until proceeding to analysis, and also to prevent any transfer of moisture content from the surroundings

Analysis of Raw Material

***Proximate Composition*:** RB powder and all-purpose flour (wheat) samples were examined for their proximate composition, such as NFE, crude fat, crude protein, ash, moisture, and crude fiber by methods prescribed by AOAC (2010).

***Mineral Profiling of Wheat Flour and Rice Bran*:** The mineral profile of wheat flour and rice bran was examined by employing the Flame photometer and the Atomic Absorption spectrophotometer method, as reported in the literature (Shahzad et al., 2021). The investigation was conducted in two stages: part 1 on digestion and part 2 on the flame photometer, as follows: Digestion is usually performed to remove organic biomass from the sample to accurately assess the mineral content (inorganic). A sample (0.2 g) was taken in a digestive conical flask, followed by the addition of 10 and 5 mL of HNO_3 and H_2SO_4. Flasks containing the sample and acid mixture were heated for about 2 hours until a transparent and clear solution was obtained, which was brought to room temperature and subjected to filtration through a Whatman filter. paper. The solution was then shifted to a volumetric flask, and a total volume of 50 mL was prepared by the addition of distilled water. The resulting solution was run on a flame photometer for the minerals analysis. Different frequencies and wavelengths, along with lamp current value, were employed as stated in Table No. 1. Obtained outcomes were reported in mg /kg on dry weight basis of the sample.

Table 1. Parameters for Atomic Absorption Spectroscopy (AAS) Analysis.

Sr.	Mineral	FF rate (L/min)	Lamp-current (mA)	Wave length (nm)
1.	Na	2.0	9.0	589.0
2.	Ca	2.2	9.0	422.0
3.	Fe	2.2	9.0	510.0
4.	K	2.8	9.0	766.5
5.	P	2.0	9.0	830.0
6.	Mg	2.0	9.0	285.2

Sodium (Na); Iron (Fe); Magnesium (Mg), Calcium (Ca); Phosphorus (P), and Potassium (K);

***Treatment plan*:** All-purpose flour (wheat) was partially substituted with the selected levels of RB powder as described in Table 2, as follows:

Table 2. Treatment Plan.

Treatments	RB Powder (RBP) (%)	All-purpose Flour (%)
Control	0	100
T4	20	80
T3	15	85
T2	10	90
T1	5	95

***Development of Cake Rusk*:** RB powder was added in different selected ratios, *i.e.*, (20, 15, 10, and 5%), in the cake rusk production as shown in Table 2. The powdered ingredients were weighed according to recipe and mixed in the bowl for almost 3 to 5 minutes. Shortening was added to the recipe mix and distributed uniformly. After that, eggs were added during mixing in the mixer, and the operation was continued for approximately 5 minutes. Batter was added in the pan & baking proceeded at 180°C, which continued for 20 to 25 minutes in the baking oven. After a second baking, the cake rusks were cooled down at room temperature (25±2°C). Polyethylene bags were used for packing of cake rusks. Cake rusks were placed for cooling at room temp, then they are packed in vacuumed LDPE (low-density polyethylene) bags until further analysis (Kim et al., 2021).

Analyses of cake Rusk

***Proximate Composition*:** Prepared cake rusks were examined for their proximate composition, such as NFE, crude protein, ash, crude fat, moisture, and crude fiber by methods prescribed by AOAC (2010). The results were statistically analyzed to check for any significant mean differences.

***Mineral profiling of cake rusk*:** The mineral profile of developed cake rusk using different treatments was examined as previously stated by Shahzad et al., (2021) and described in 2.4.

***Physical Attributes of Cake Rusk*:** The cake rusks were randomly selected for thickness, spread ratio, and diameter in physical analyses, as prescribed earlier (Ho & Abdul Latif, 2016). The spread ratio was determined, dividing the diameter by the thickness of the cake rusk (Javaria et al., 2025).

***Sensory Evaluation*:** A hedonic scale with 9 points was used for the sensory evaluation of cake rusk samples. The following parameters on scale were Excellent (9), Very Good (8), Good (7), Like Extremely (6), Like Very Much (5), Like Moderately (4), Neither Like nor Dislike (3), Dislike Slightly (2), and Dislike (1). A board of trained persons, related to the field of study, was selected to judge the sensory attributes of cake rusks. The given scores were statistically analyzed after evaluation of cake rusks.

***Statistical Analysis*:** The drawn results were analyzed through ANOVA, analysis of variance, employing SPSS Ver. 25, and Fisher's Least Significant Difference (LSD) test was employed to treat the means.

RESULTS AND DISCUSSION

***Basic Chemical Composition of Wheat Flour & RB*:** In the current scientific venture, wheat flour and RB powder were investigated for their basic chemical composition to obtain the initial chemical profile and for the commencement of a comparison between RB powder and wheat flour. For this purpose, different standard approaches were applied, and the obtained results were statistically analyzed as follows:

In Table 3, mean values for basic chemical characterization of wheat flour and RB powder are provided. The average moisture in wheat flour and RB powder was investigated. The moisture content examination clearly depicts that the maximum 13.54 g/100g was observed in wheat flour samples, and the minimum content was detected in RB powder (12.93 g/100g. Regarding protein content, the highest protein content (13.85 g/100g) was found in RB powder samples, with the lowest concentration (10.43 g/100g) defined in wheat flour samples. Protein percentage in grain or legume flours is of significant importance owing to their numerous inherent functional properties and characteristics, *i.e.*, water absorption, stretchiness/viscoelasticity, strength of dough, volume of loaf, texture, including dough cohesiveness. In baked products, fat is considered the best tenderizer. It also acts as a coating agent on protein molecules, against water, and subsequently slows down gluten development. In addition, fat content shortens the strands of gluten. Fat content analysis results showed that, on average, 1.20±0.22 g/100g and 20.86±2.65 g/100g were detected in wheat flour and RB powder, respectively. This analysis further depicted that the maximum 20.86 g/100g fat content was noted in RB powder samples, and the least level was observed in wheat flour 1.20 g/100g samples. Meanwhile, fiber content examination clearly depicts that the highest (12.73 g/100g) fiber content was found in RB powder samples, and the lowest concentration (0.53 g/100g) was defined in wheat flour samples. In nutritionally enhanced baked food development, fiber from cereal bran is a useful ingredient. Fiber plays a significant role in supporting regular body functions and helps to reduce digestive problems. Cereal brans, particularly RB, is full of dietary fiber which can be consumed by humans. In baked products, fiber content typically comes from whole grains that are used in the preparation of muffins, crackers, and as well as cookies. Rice bran is rich in fiber that is safe and beneficial for human consumption. Meanwhile, ash content examination clearly depicts that the highest 11.85 g/100g ash content was detected in RB powder samples, with the far least concentration defined in wheat flour i.e. 1.32 g/100g samples. Ash content was mainly used to measure the

inorganic mass, *i.e.*, minerals, as well as the vitamin profile. In addition, the carbohydrate content depicted an average carbohydrate level in wheat flour of 73.23±1.21 g/100g, and RB powder, 30.49±2.65 g/100g. The examination clearly depicts that the highest carbohydrate content in wheat flour samples, and the minimum concentration in RB powder. In the present study, it was discovered that RB powder, in contrast to wheat flour, was discovered to be significantly higher in the context of their proximate chemical characterization, i.e., fat, protein, fiber, and ash content. Similar outcomes were also reported by (Bunde et al., 2010; Sharif et al., 2009; Younas et al., 2011).

After checking the mean difference by introducing one-way analysis of variance, which shows a significant mean difference between different prepared flours at the level ($p < .05$). The outcomes showed that on an overall basis, RB powder was found to be superior in terms of nutritional value.

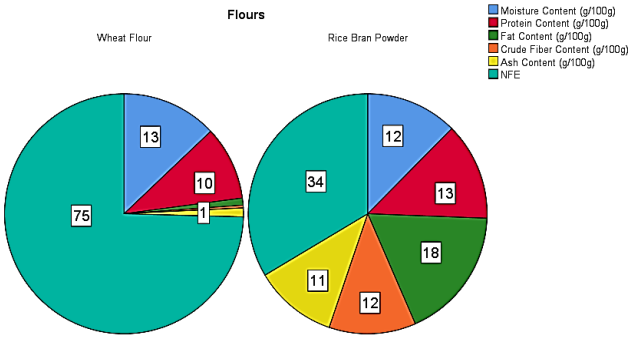

Figure 1. Pie Chart for Proximate Chemical Profile of Wheat Flour and RB Powder.

In this figure, an estimated marginal means (Pie chart) for basic chemical composition in different selected flours (wheat flour and RB powder) was conducted. Further, each slice is color-filled as well as labeled to ease in differentiation.

Table 1. Proximate Chemical Composition of Wheat Flour and RB Powder.

Attribute (g/100g)	Flours	Mean
Moisture	Wheat Flour	13.54±0.53[a]
	RB Powder	12.93±0.48[a]
Crude Protein	Wheat Flour	10.43±0.42[b]
	RB Powder	13.85±0.72[a]
Crude Fat	Wheat Flour	1.20±0.22[b]
	RB Powder	20.86±2.65[a]
Crude Fiber	Wheat Flour	0.53±0.14[b]
	RB Powder	12.73±0.87[a]
Crude Ash	Wheat Flour	1.32±0.12[b]
	RB Powder	11.85±0.57[a]
NFE	Wheat Flour	73.23±1.21[a]
	RB Powder	30.49±2.65[b]

Each value is an average of 3 replicates; Values are given in (Mean ± *SD*)

***Mineral Composition of RB and Wheat Flour*:** Cereal grain's bran part is described to display a good mineral profile, such as calcium (Ca), iron (Fe), magnesium (Mg), zinc (Zn), and manganese (Mn). The innate characteristic of RB powder makes it a potential constituent for the development of functional food and its derivatives (Etiosa et al., 2017). In this study, wheat flour is partially substituted with RB powder to fulfil the nutritional deficiencies, and both flours were investigated for their mineral profile, and the statistically analyzed obtained results were presented as in Table 4.

Table 4. Mineral Profile of Wheat Flour (WF) and RB Powder (RBP).

Attribute (g/100g)	Flours	Mean
Calcium	Wheat Flour	19.37±0.56[b]
	RB Powder	59.17±2.20[a]
Iron	Wheat Flour	1.15±0.06[b]
	RB Powder	17.82±0.73[a]
Magnesium	Wheat Flour	22.94±0.87[b]
	RB Powder	787.84±6.42[a]
Phosphorus	Wheat Flour	136.86±1.74[b]
	RB Powder	1680.22±16.16[a]
Potassium	Wheat Flour	134.19±1.12[b]
	RB Powder	1490.11±4.56[a]
Zinc	Wheat Flour	1.01±0.14[b]
	RB Powder	6.72±0.64[a]
Sodium	Wheat Flour	2.29±0.30[b]
	RB Powder	5.67±0.63[a]

Each value is an average of 3 replicates; Values are given in (Mean ± *SD*)

Table 4 depicts mineral profile of wheat and RB powder samples, and among these, the calcium content, on average, in wheat flour (19.37±0.56 mg/100g) and RB powder (59.17±2.20 mg/100g) was found. Meanwhile, the maximum calcium content was detected in RB powder, whereas the lowest calcium levels were noted in wheat flour. The results of Iron (Fe) content in both wheat and RB powder samples showed that, on average, amounts of 1.15±0.06 mg/100g and 17.82±0.73 mg/100g, respectively, were recorded in wheat flour and RB powder. The average Magnesium in wheat flour was 22.94±0.87 mg/100g and 787.84±6.42 mg/100g in RB powder was noted, with the highest level detected in RB powder and lowest in wheat flour samples. The results of phosphorus (P) content were also recorded as the average content in wheat flour is 136.86±1.74 mg /100g and 1680.22±16.16 mg/100g in RB powder, accordingly. The results of potassium (K) content depicted that an average amount of this mineral in wheat flour was 134.19±1.12 mg/100g, and in RB powder it was 1490.11±4.56 mg/100g, respectively. The Zinc (Zn) was also investigated, and the results exhibited that on average basis Zn in wheat flour was present as 1.01±0.14 mg/100g, while 6.72±0.64 mg/100g was

found in RB powder with the highest value in RB powder samples, and the lowest in wheat flour samples. Lastly, the results for sodium (Na) content were presented as in wheat flour an average of 2.29±0.30 mg/100g and in RB powder was 5.67±0.63 mg/100g. Both wheat flour and RB powder exhibited that the maximum sodium content was noted in RB powder and the lowest levels were measured in wheat flour samples. The pattern of study found the relevance as prescribed by various researchers (Bunde et al., 2010; Sharif et al., 2009; Younas et al., 2011). The mean differences among treatments were assessed at the level ($p < .05$) and by introducing One-way analysis of variance (ANOVA), which showed a significant mean differentiation between different prepared flours. The presented outcomes showed that the overall superiority in terms of mineral profile was found in RB powder.

Analysis of Cake Rusks

***Effect of Incorporating RB on the Moisture Content of Cake Rusk*:** In the present study, functional cake rusks were prepared by planned treatments and followed by an investigation for their effect on the final moisture content.

In Table 5. mean values of the moisture contents in different treatments are presented. Regarding the outcomes, on average basis, T_0 exhibited 2.90±0.28 g/100g, T_1 (2.84±0.17) g/100g, T2 (2.77±0.18) g/100g, T3 (2.70±0.17) g/100g and T4 (2.63±0.24) g/100g, respectively. On the other hand, the maximum moisture content was found in T_0 (Control) sample, containing 100% wheat flour and absolutely no concentrations of RB powder whereas the least moisture (2.68 g/100g) level was noted in T_4 sample, having 20% RB powder on the 1st day. After checking the mean difference by introducing One-way analysis of variance at the level ($p < .05$), a significant mean difference between different treatments was observed, and the multiple mean comparisons among different treatments also indicated the same. The findings about moisture content of cake rusk prepared by addition of RB powder, significantly decreased as compared to the cake rusk developed by only wheat flour and exhibited the following order; Moisture content of T_0 (100:0) *>T1* (95:05) *>T2* (90:10) *>T3* (85:15) *>T4* (80:20). A similar decrease in moisture content was reported by (Diracy Betânia et al. 2009; Sharif et al., 2009).

***Effect of Incorporating RB on the Protein Content of Cake Rusk*:** In the present study, functional cake rusks were prepared by developing treatments and followed by an investigation of their effect on final protein content.

In Table 5, descriptive analysis of protein content in different treatments was conducted. Regarding the outcomes, on average T_0 exhibited 6.10±0.54 g/100g, T_1 6.11±0.67 g/100g, T_2 6.17±0.48 g/100g, T_3 6.35±0.46 g/100g and T_4 (6.48±0.48) g/100g was diagnosed. The highest protein level (6.48 g/100g) was detected in T_4 sample, having twenty percent RB powder; on the other hand, the lowest protein content (6.10 g/100g) was found in the T_0 (Control) sample, containing only wheat flour and absolutely no concentrations of RB powder. One-way analysis of variance (ANOVA) was conducted to check the mean differences among different treatments. As far as the results are concerned, there was a significant mean difference among different treatments.

In this study, examination shows that by addition of RB powder, protein ratio of cake rusk significantly raises as compare to the cake rusk developed by only wheat flour and found in following order (Wheat Flour: RB Powder) of T0 (100:0) *<T1* (95:05) *<T2* (90:10) *<T3* (85:15) *<T4* (80:20). Similar decrease in moisture content was reported by (Diracy Betânia et al. 2009; Sharif et al., 2009).

***Effect of Incorporating RB on the Fat Content of Cake Rusk*:** Fat is used as a great tenderizer in baked products or derivatives. Meanwhile, fat also acts as a coating agent against water on protein molecules, which can consequently slow down the development of gluten. In addition, fat is also utilized to shorten the gluten strands. Functional cake rusk was prepared by developing treatments and followed by an investigation of their effect on the final fat content.

Different treatments were conducted for the descriptive analysis of fat content, as mentioned in Table 5. As far as the results are concerned, it was noted that an average content was recorded in T_0 as 16.88±1.75 g/100g, T_1 (17.17±1.80 g/100g), T_2 (17.47±1.95 g/100g), T_3 (18.21±1.98 g/100g), and T_4 (18.97±1.80 g/100g). It was noticed that the highest content of fat (18.97 g/100g) was detected in the T_4 sample, which had twenty percent RB powder. In contrast, the minimum lipid content (16.88 g/100g) was recorded in T_0. The one-way analysis of variance presented a significant mean difference between different treatments. Post ANOVA analysis was conducted to generate multiple mean comparisons between different treatments. In this study, examination shows that by addition of RB powder, fat content of cake rusk significantly increased as compare to the cake rusk developed with only wheat flour, and further found in following order of T_0 (100:0) *<T1* (95:05) *<T2* (90:10) *<T3* (85:15) *<T4* (80:20). Similar increase in fat content was also studied by (Diracy Betânia et al. 2009; Sharif et al., 2009).

***Storage Effect of Incorporating RB on the Fiber Content of Cake Rusk*:** The fiber is referred to as an undigestible carbohydrate present in whole grains, mainly. It is used in the preparation of crackers, muffins as well as, cookies, and tortillas. In this part, developed treatments were investigated for their effect on fiber content, and the results are presented in Table 5. Descriptive analysis of crude fiber content in different treatments was conducted. As far as the outcomes are concerned, on average, in T_0 1.18±0.32 g/100g, T_1 (1.61±0.21 g/100g), T_2 (2.12±0.20 g/100g), T_3 (2.24±0.21 g/100g), and T_4 (2.57±0.21 g/100g) fiber was observed. In addition, the highest fiber level (2.57 g/100g) was investigated in the T4 sample, which had twenty percent RB powder. In contrast, the lowest fiber content of 1.18 g/100g

Table 5. Effect of Incorporating RB on the Proximate Composition of Cake Rusks.

Treatments	Ash (g/100g)	Protein (g/100g)	Fat (g/100g)	Fiber (g/100g)	Carbohydrate (g/100g)	Moisture (g/100g)
T_0	1.11±0.27^{e}	6.10±0.54^{e}	16.88±1.75^{e}	1.18±0.32^{e}	71.84±2.26^{a}	2.90±0.28^{a}
T_1	1.46±0.30^{d}	6.11±0.67^{d}	17.17±1.80^{d}	1.61±0.21^{d}	70.82±2.08^{b}	2.84±0.17^{b}
T_2	1.71±0.40^{c}	6.17±0.48^{c}	17.47±1.95^{c}	2.12±0.20^{c}	69.76±1.93^{c}	2.77±0.18^{b}
T_3	2.17±0.25^{b}	6.35±0.46^{b}	18.21±1.98^{b}	2.24±0.21^{b}	68.33±2.37^{d}	2.70±0.17^{c}
T_4	2.43±0.19^{a}	6.48±0.48^{a}	18.97±1.8^{a}	2.57±0.21^{a}	66.93±2.13^{e}	2.63±0.24^{d}

Each value is an average of three replicates

Control: 100% Wheat Flour: 0% RB Powder; T_1: Wheat Flour95 %: RB Powder 5%; T_2: Wheat Flour 90 %: RB Powder 10%; T_3: Wheat Flour 85 %: RB Powder 15%; T_4: Wheat Flour 80 %: RB Powder 20%

Means that do not share a letter $^{a\ b\ c}$ in the column is significantly different at the level ($P< 0.05$)

was observed in the T_0 (Control) sample, containing only wheat flour and absolutely no concentrations of RB powder.

The results of ANOVA presented a significant mean difference among different treatments. Furthermore, post-ANOVA analysis was conducted to generate multiple mean comparisons between different treatments. In this study, examination shows that by RB powder addition, fiber content of cake rusk significantly raised as compare to the cake rusk prepared with only wheat flour and further found in following order as shown; T0 (100:0) <*T1* (95:05) <*T2* (90:10) <*T3* (85:15) <*T4* (80:20). Similar increase in fat content was also studied by (Diracy Betânia et al. 2009; Sharif et al., 2009).

***Effects of Incorporating RB on the Ash Content of Cake Rusk*:** Ash examination is mainly done to examine the inorganic profile, as minerals. In this part, developed treatments were investigated for their effect on ash content, and the results are presented in Table 5. The different treatments were subjected to descriptive analysis of ash content. As far as the outcomes are concerned, on average, in T_0 1.11±0.27 g/100g, T_1 (1.46±0.30 g/100g), T_2 (1.71±0.40 g/100g), T_3 (2.17±0.25 g/100g), and T_4 (2.43±0.19 g/100g) ash contents were observed. Meanwhile, the lowest ash content (1.11 g/100g) was noted in the T_0 (Control) sample, containing only wheat flour and absolutely no concentrations of RB powder. In contrast, the maximum ash (2.43/g/100g) level was investigated in the T_4 sample, having twenty percent RB powder.

The findings of ANOVA illustrated that there was a significant mean difference among different treatments. In this study, examination shows that by adding RB powder, ash content of cake rusk significantly increased as compare to the cake rusk developed with only wheat flour and further found in following order of T_0 (100:0) <*T1* (95:05) <*T2* (90:10) <*T3* (85:15) <*T4* (80:20). Similar increase in ash content was also studied by (Diracy Betânia et al. 2009; Sharif et al., 2009).

***Effect of Incorporating RB on the Carbohydrate Content (NFE) of Cake Rusk*:** In this part, developed treatments were investigated for their effect on carbohydrate content, and the results are as follows: Descriptive analysis of carbohydrate content in different treatments was conducted. As far as the outcomes are concerned, on an average basis, T_0 contained 71.84±2.26 g/100g, T_1 (70.82±2.09 g/100g), T_2 (69.76±1.94 g/100g), T_3 (68.33±2.37 g/100g), and T_4 (66.93±2.13 g/100g) of carbohydrate content. Meanwhile, the least carbohydrate content (66.93 g/100g was observed in T4 sample, which had twenty percent RB powder, whereas the maximum carbohydrate (71.84 g) g/100g was investigated in T_0 (Control) sample containing only wheat flour and absolutely no concentrations of RB powder. After checking the mean difference by introducing One-way analysis of variance (ANOVA), it was shown that there is a significant mean difference among different treatments at the level ($p< .05$). In this study, examination shows that by adding RB powder, digestible carbohydrate content of cake rusk significantly decreased as compare to the cake rusk prepared by using only wheat flour and further found in the order of T_0 (100:0) >*T1* (95:05) >*T2* (90:10) >*T3* (85:15) >*T4* (80:20). Similar outcome regarding carbohydrate content was also reported by scientists (Diracy Betânia et al. 2009; Sharif et al., 2009).

***Macro Mineral Assessment of Cake Rusk*:** Cereal grain's bran part is reported to display a rich mineral profile, such as Ca, Fe, Mg, Zn, and Mn. The inherent characteristics of RB powder, containing minerals, make it a potential constituent for the development of functional food products & derivatives (Etiosa et al., 2017)s. On the other hand, all-purpose wheat flour investigated for mineral content confirms very low concentrations of essential minerals. Minerals are greatly required for the proper growth of cells and the development of the human body. ANOVA was conducted to present a significant mean difference among different treatments for each mineral, and observed at the level $p< 0.05$. In this study, examination shows that by adding RB powder, Na, Ca, Mg, P, K, Fe and Zn content of developed functional cake rusks significantly increased in contrast to the treatments having only the wheat flour and further found in the following order of T_0 (100:0) <*T1* (90:10) <*T2* (85:15) <*T3* (80:20) <*T4* (75:25) at level (P< .05).

This pictorial presentation (Fig.2) in a 3D-Bar graph for macro mineral contents depicted that different treatments show an incline from T_0 to T_4 as the RB powder concentration increases

Table 6. Effect of introducing RBPowder on the Sensory Profile of Cake Rusk.

Treatments	Sensory Attributes					
	Crumb colour	Crust colour	Aroma	Flavor	Texture	Overall acceptability
Control	7.0^{e}	7.0^{e}	8.0^{e}	7.0^{e}	7.0^{e}	7.20^{e}
T_1	7.5^{d}	7.2^{d}	8.2^{d}	7.4^{d}	7.2^{d}	7.50^{d}
T_2	7.8^{c}	7.5^{c}	8.6^{c}	7.7^{c}	7.5^{c}	7.82^{c}
T_3	8.2^{b}	7.9^{b}	8.8^{b}	7.9^{b}	7.8^{b}	8.12^{b}
T_4	8.7^{a}	8.4^{a}	9.0^{a}	8.6^{a}	8.2^{a}	8.58^{a}

The descriptive analysis for macro minerals was investigated.

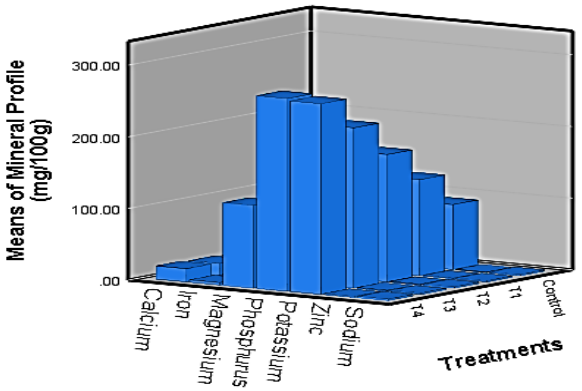

Figure 2. 3D-Bar graph for mineral content in different Treatments.

***Physical Analysis of Cake Rusk*:** ANOVA was conducted to check the mean difference in physical properties among different developed treatments. There was a significant mean difference at each physical attribute among different treatments *(P< .05*). Post ANOVA analysis was conducted to generate multiple mean comparisons of different treatments. In this study, an inverse proportional relation was observed, which shows that by increasing RB powder concentrations in functional cake rusk, physical characteristics tend to decrease significantly at a confidence level of 95 percent. The pictorial presentation in the bar graph for physical parameters is also given in Figure 3.

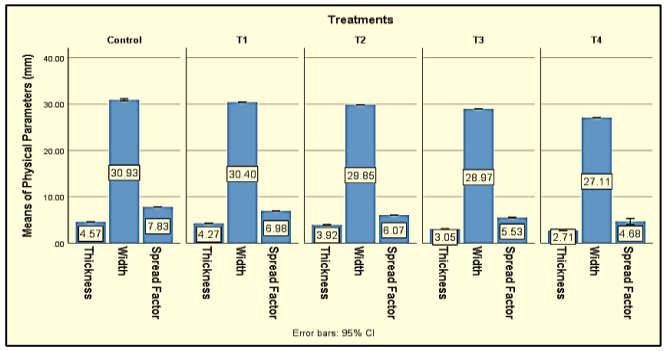

Figure 3. Bar graph for physical parameters in different Treatments.

***Sensory Evaluation of Cake Rusk*:** In present study, functional cake rusks were prepared by substituting different selected concentrations of RB powder with conventional all-purpose wheat flour however, developed treatments were investigated for their effect on sensory characteristics meanwhile, obtained results were statistically analyzed to check any significant mean difference. The ANOVA findings presented that there was a significant mean difference at each sensory parameter among different treatments *(P< .05*).

It was concluded that with the addition RB powder in the preparation of cake rusk, the overall acceptance was enhanced significantly. For the meantime, results from T_3 (8.12) and T_4 (8.58) having 15% and 20% RB powder levels, respectively, display that RB powder can be added in a specific amount as described earlier to fulfil the nutritional gap generated by conventional cake rusk principally prepared with wheat flour, without losing any sensory attributes of product at level (P< .05). The observations & results of the present study relate to the results of Javaria et al. (2025).

Conclusions: The current study was planned to produce cake rusk by incorporating RB in order to enhance its nutritional profile, mainly dietary fiber. serves as an effective strategy for value addition, enhancing both the nutritional profile and several functional attributes of the product. Cake rusk was processed by mixing RB with all-purpose flour at various ratios like 5%, 10%, 15% and 20%. The final product obtained was successfully analyzed by different physical and chemical methodologies. The results after chemical analysis explicated that incorporation of RB can significantly increase dietary fiber, mineral, and protein content of cake rusk from T_0 to T_4 as the RB powder concentration increases. Whereas, the physical properties of cake rusk, such as diameter, thickness, width, and spread factor, were remarkably affected by the enhancement in the ratio of bran, and also by the stabilization method. Hedonic score system (9-points) was used for sensory evaluation, which reveals that the highest (8.58) score for overall acceptability was observed in T_4 (20% RB Powder) samples, as far lowest (7.2) score was observed and detected in T_0 (Control) sample, comprising absolutely no RB powder concentrations. Thus, supplementation of RB at a 20% level each would improve and enhance the nutritional quality without badly affecting the sensory parameters of cake rusks.

Furthermore, fortification with RB in rusks exhibits potential to significantly improve essential minerals, bioactive components (such as γ-oryzanol and tocopherols), and antioxidant potential of the cake rusk without causing major adverse effects on its physical or sensory qualities up to an optimal substitution level. Overall, the findings confirm that RB fortification represents a promising, cost-effective approach to developing healthier bakery products, promoting the utilization of a nutrient-rich milling by-product often underused in the food industry. This value addition not only contributes to waste reduction and improved sustainability but also provides an opportunity for the food sector to diversify functional and fiber-enhanced baked goods. Conclusively, it can be drawn that cake rusk prepared from RB has greater prospective in food applications, especially including functional bakery items. Further studies may explore consumer behavior, shelf-life enhancement techniques, and functional health claims to expand the commercial applicability of rice-bran-fortified bakery products.

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***Ethical statement*:** The research involved physicochemical analyses and laboratory-based product development only. No human or animal subjects were used. Hence, ethical approval and informed consent did not apply to this study.

***Availability of data*:** All data supporting the findings of this study are included within the article and its supplementary materials.

***Consent to participate*:** Written informed consent was obtained from all participants before their involvement in the sensory evaluation. Participation was voluntary, and the confidentiality of the participants was maintained throughout the study.

***Informed consent*:** Informed consent was not required because the study involved laboratory-based product development and physicochemical analyses only, with no involvement of human or animal subjects.

***Consent for publication*:** Consent for publication was not required because the manuscript does not contain personal data, images, or identifiable information of any participants.

***SDGs addressed*:** Zero Hunger: Good Health and Well-Being: Industry, Innovation, and Infrastructure.

***Policy referred*:** Development of functional and fortified food products; Improvement of dietary fiber, micronutrient, and antioxidant intake; Addressing malnutrition through nutrient-dense bakery products.

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